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# Total apparent digestibility and nitrogen balance in Cinta Senese pigs: utilization of field bean (*Vicia faba* L.)

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## ABSTRACT

This work aimed to study the digestive capacity and the nitrogen balance in Cinta Senese pigs in comparison with Large White pigs, employing field bean and soybean as protein sources. Twelve 5-month old barrows, 6 Cinta Senese (CS) and 6 Large White (LW), were submitted to trials in metabolism cage to determine apparent digestibility and nitrogen balance of diets containing soybean meal (S diet) or field bean (F diet), 10% and 20% respectively, as the protein source. CS showed lower digestibility coefficients for all the nutritive fractions than LW pigs (DM: 85.33% vs. 82.87%; CP: 86.38% vs. 84.17%; ADF 51.35% vs. 43.31%). Nitrogen retention, also, was less favorable in CS pigs, which showed a 20% higher excretion (fecal + urinary) value of total N ingested (59.88% vs. 48.60%). Differences between the diets were limited. Field beans, containing only 0.25% of tannin as used here, appear a valuable protein source in pig nutrition, even in local breeds such as CS.

**Key words:** Cinta Senese, Pig, Apparent digestibility, Nitrogen balance, Field beans.

## RIASSUNTO

### DIGERIBILITÀ APPARENTE E BILANCIO AZOTATO NEL SUINO CINTA SENESE: UTILIZZAZIONE DEL FAVINO (*VICIA FAB* L.)

*Il presente lavoro si propone di studiare le capacità digestive e il bilancio azotato nella razza suina Cinta Senese a confronto con la razza migliorata Large White, e impiegando diete contenenti come sorgente proteica favino e soia. Dodici suini maschi castrati, 6 Cinta Senese (CS) e 6 Large White (LW), sono stati sottoposti a prove di digeribilità ed utilizzazione metabolica dell'N. Sono state utilizzate 2 diete interamente vegetali. L'apporto proteico era garantito nella dieta F da semi integrali di favino (20%) e nella dieta S dalla farina d'estrazione di soia (10%). I dati sono stati analizzati tramite analisi della covarianza con effetti fissi razza e dieta; effetto casuale soggetto entro razza; effetto continuo della variabile indipendente "peso vivo a inizio prova" o "ingestione giornaliera di azoto", a seconda del parametro analizzato. La Large White ha digerito di più la sostanza secca (85,33% vs. 82,87%), e tutte le frazioni della sostanza organica, in particolare la proteina per oltre il 2% (86,38% vs. 84,17%). Molto elevate sono state le differenze per quanto riguarda le frazioni fibrose ed in particolare la digeribilità dell'ADF è risultata più elevata nella razza migliorata di oltre 8 punti percentuali (51,35% vs. 43,31%). L'utilizzazione dell'azoto e dell'energia durante le fasi del processo digestivo e metaboli-*

co è risultata peggiore nella CS che ha mostrato, rispetto alla razza migliorata, più elevati valori di escrezioni azotate proporzionalmente all'ingestione (59,88% vs. 48,60%). Il rendimento dell'EG delle diete in EM è stato peggiore nella CS (14,71 vs. 15,12 Mj/kg DM). Il confronto tra le diete ha mostrato che l'impiego del favino non compromette l'utilizzazione digestiva della dieta nel complesso e consente ritenzioni azotate analoghe a quelle della soia; il favino quindi può risultare una valida fonte proteica alternativa.

Parole chiave: Cinta Senese, Suini, Digeribilità, Bilancio azotato, Favino.

## Introduction

The renewed interest in and the increasing importance of local pig breeds, also in terms of number of animals, call for an evaluation of their performances. Just a few years ago the use of these breeds was finalized to the utilization of spontaneous and marginal resources, but the recent strong economic exploitation of their typical products increased interest in their use also on specialized farms where there is a tendency to augment the carrying capacity of the pastures in order to increase the gross product. The use of feeds that supplement or completely substitute woodland resources make it appropriate to study the nutritional requirements of these breeds and their performances. Actually, the local pigs could sensibly differ from the improved ones in which the genetic improvement certainly modified both the productive performances and the relative metabolic processes. Only few researchers (Zicarelli *et al.*, 1979; Freire *et al.*, 1998) have studied the digestive capacity and the metabolic utilization of protein in pigs of native breeds and the results are contradictory depending on the diets and on the age of the experimental animals. Moreover, in the feeding of local pigs, the usual protein sources such as soybean meal are often

substituted by traditional legume seeds such as field beans in which tannin content may influence the digestive utilization (Jansman *et al.*, 1993). The present work aimed to study the digestive capacity and the nitrogen balance in Cinta Senese pigs, an autochthonous breed usually reared on free-range, while employing the Large White breed as control since its performances are known. The field bean, a traditional feed in local pig rearing, has been employed as the protein source in comparison with soybean, the use of which worries the production sector with regard to the possibility of its genetic modification.

## Material and methods

Twelve barrows (6 Cinta Senese (CS) and 6 Large White (LW)), aged 5 months at the start of the experiment, were submitted to digestibility and nitrogen balance trials using individual metabolic cages to collect feces samples and total urine. The subjects of the two breeds had the same age but different weights due to the higher growth capacity of LW compared with CS (Table 1). Each trial in cage lasted 7 days and was preceded by a 7-day period of adaptation on floor.

The period in cage was composed of a phase of adaptation to the cage (3 days) and a phase (4

Table 1. Body weight of pigs.

		Breed		Diet	
		Cinta Senese	Large White	Field bean	Soybean
Medium weight	kg	51.8 ± 13.7	69.6 ± 12.1	60.7 ± 17.5	60.7 ± 13.9
Minimum weight	"	29.2	46.8	29.2	33.4
Maximum weight	"	78.0	94.6	94.6	86.8

Table 2. Scheme of experiment.

Trial week	Large White		Cinta Senese	
	Group1	Group2	Group1	Group2
1	Soybean	/	Soybean	/
2	/	Field bean	/	Field bean
3	Field bean	/	Field bean	/
4	/	Soybean	/	Soybean
5	Soybean	/	Soybean	/
6	/	Field bean	/	Field bean
7	Field bean	/	Field bean	/
8	/	Soybean	/	Soybean

Each group is composed of three pigs  
/ adaptation on floor

days) of collection of feces samples and of total urine as proposed by Schiavon *et al.* (1996). A Latin square design was employed. For each genetic type, two groups of animals were formed and were alternatively employed so that the six cages were contemporarily occupied by three subjects for each genetic type fed the same diet. The detailed scheme of the experimental design is reported in Table 2.

The diets, of exclusive vegetable origin, were iso-nitrogen and without added amino acids to allow the right comparison between the two protein sources: Field bean (F) and soybean meal (S). Field bean had a tannin content of 0.25%, considered as a low-medium level according to the classification proposed by Jansman *et al.* (1993). The mixed diets were pelleted to avoid the possibility of the animal choosing the single ingredients. Formulation and chemical composition of the diets are reported in Table 3. Diets were supplied on a basis of 90 g/kg of metabolic weight (MW), computed whenever the animals were transferred to the cages. Metabolic cages were provided with a drinking trough and manger and, because of their conformation, it was possible to recover the full urine produced in flasks in which 20 cc of 8N sulphuric acid were added to avoid the volatilization of ammoniacal nitrogen (Sardi *et al.*, 1998).

The total urine produced by each subject was weighed daily and subsequently sampled. Three times a day samples of feces for each subject were

collected in order to create the individual daily sample. Feed intakes were controlled daily both during the period on floor and during the experimental period in cage.

Feed and feces were submitted to proximate analysis and to AIA determination in order to provide the apparent digestibility according to the method proposed by Van Keulen and Young (1977); fibrous fractions also were determined (Van Soest *et al.*, 1991). Urine samples were analyzed for nitrogen content according to the Kjeldhal method. All the analytical methods used for feed, feces and urine were those reported by Martillotti *et al.* (1987).

Data were analyzed by MIXED Procedure (SAS, 1988) using the following model:

$$Y_{ijkl} = \mu + B_i + D_j + S_{ik} + b^*X_{ijk} + E_{ijkl}$$

Where Y = l<sup>th</sup> observation on k<sup>th</sup> subject; B = fixed effect of breed; D = fixed effect of diet; S = random effect of subject within breed; X = covariate (weight at trial start or N daily intake, depending on examined parameter); E = random error. Breed x Diet interaction never resulted significant and has been excluded from the final model.

## Results and discussion

Table 4 reports feed intakes and apparent digestibility coefficients of the diets and of the

dietary components. Feed intakes were greater for Large White pigs because the experimental design had foreseen the food amount proportional to metabolic weight, surely higher for this breed. Feed intakes were not different between diets.

As regards digestibility coefficients, the comparison between breeds showed a systematic advantage of Large White pigs. This breed digested the crude protein 2% more than CS and similar results were found by Freire *et al.* (1998) comparing LW with Alentejano, a rustic Portuguese pig breed. The improved breed showed better results (around 1% better) even in terms of digestibility of ether extract and of nitrogen-free extract, whereas for non structural carbohydrates the difference was not significant. The difference between diets for crude fiber was high, even if not significant, due to the higher residual variability. Such component of the diets, well-known as low digestible for

monogastric animals, showed values similar to those related by Jansman *et al.* (1993) which used a type of field bean with a tannin content ranging from 0.02 to 0.98 %. Looking in depth at the fibrous fractions the differences between breeds resulted significant, with the exclusion of lignin, and in all the cases the local breed demonstrated worse results. These results disagree with those reported by Freire *et al.* (1998) which found greater digestibility of fiber and its fractions in the rustic breed compared with the improved one, but it has to be noted that they used diets with low fiber content. On the contrary, Zicarelli *et al.* (1979) didn't find differences in digestive capacity among Large White and three Italian local breeds such as Casertana, Calabrese and Cavallina Lucana, when compared at the same age and fiber content of the present trial.

The comparison between diets shows that the

Table 3. Ingredients and chemical composition of diets.

		Diet	
		Field bean	Soybean
Ingredients			
Maize	%	15	15
Barley	"	29	39
Wheat bran	"	20	20
Field bean	"	20	---
Soybean meal	"	---	10
Maize gluten feed	"	10	10
Premix <sup>1</sup>	"	6	6
Composition			
Crude Protein	% dm	16.29	15.92
Ether extract	"	2.56	2.85
Crude fiber	"	5.88	5.98
NSC	"	46.93	46.84
NDF	"	26.13	25.88
ADF	"	7.4	6.58
ADL	"	1.74	1.62
Ash	"	8.09	8.51
Lysine <sup>2</sup>	"	0.77	0.70
Methionine <sup>2</sup>	"	0.21	0.29
Gross energy	Mj/kg dm	17.76	17.72

<sup>1</sup> CaCo<sub>3</sub>=2.8 %; NaCl=0.4 %; trace minerals and vitamins=1 %; lignosulphite=1.8 %.

<sup>2</sup> Calculated from tabulated data

digestive utilization of field bean was comparable to that of soybean. Particularly, the digestibility coefficient of protein, analogous between the two diets, as already reported by other Authors (Jansman *et al.*, 1993), offers reassurance with respect to the risk of reduced protein assimilation using field bean. The two diets presented quite a high level of fiber (around 6%) that could produce drawbacks in the digestibility of dry matter. As regards the values found in literature for diets with the same amount of fiber, the results of the present trial seem comparable to those of Nasi *et al.* (1995), and 10% lower than those of Schiavon *et al.* (1996) but clearly higher than those related by Buraczewska *et al.* (1996). Digestibility of crude fiber in diet S resulted almost 10 percentage points higher than in diet F. The size of this result is such that it could not be ascribed to the different digestibility of the fiber of the discriminant feed (field bean or soy bean meal), considering its moderate contribution to the total fiber of the diet. It is instead possible that the tannin of the field bean, even if does not negatively affect

intake, reduced the intestinal fermentative activity and consequently the apparent digestibility of the fiber. Similar results were obtained by Jansman *et al.* (1993), comparing varieties of field bean with different levels of tannin. Such hypothesis was not confirmed by the analysis of digestibility of the fibrous fractions which underlines the fact that diet effect was not significant and, for the cellulose, this value was even favorable for field bean diet. The high values of digestibility of the lignin could be related to the fact that part of it was solubilized by the digestive juices upon the effect of alkaline pH in the duodenum. Literature rarely reports such parameters but a study carried out with various diets relates a great variability for apparent digestibility of the lignin (Noblet *et al.*, 1993).

Table 5 reports the results regarding nitrogen utilization. The different weights of the animals of the two breeds involved a different amount of food intake (90 g/kg MW) as reported in Table 4 and thus the data of nitrogen balance were expressed on MW using the ingested nitrogen as covariate.

Table 4. Feed intake and apparent digestibility of dietary components of the ingested diets.

		Breed		Diet		RSD
		Cinta Senese	Large White	Field bean	Soybean	
Daily intake amount:						
- Dry matter	g	1541 b	1944 a	1745	1740	71.99
- Crude protein	"	248 b	312 a	284 a	276 b	11.75
Digestibility:						
- Dry matter	%	82.87 b	85.33 a	83.71	84.49	3.96
- Organic matter	"	84.88 b	87.09 a	85.57	86.40	3.51
- Crude protein	"	84.17 b	86.38 a	85.12	85.42	3.58
- Ether extract	"	91.52 b	92.78 a	91.54 b	92.76 a	2.19
- Crude fiber	"	46.70	54.15	45.83 b	55.01 a	16.51
- Nitrogen-free extract	"	88.16 b	89.94 a	88.92	89.17	2.67
- NDF	"	68.42 b	73.15 a	70.46	71.11	7.39
- ADF	"	43.31 b	51.35 a	49.32	45.34	13.24
- ADL	"	29.83	39.41	34.73	34.52	18.64
- Cellulose	"	47.57 b	55.10 a	53.81	48.87	12.18
- Hemicellulose	"	77.58 b	81.13 a	78.81	79.90	5.4
- NSC	"	95.78	96.36	95.65 b	96.49 a	1.32

a, b: within criterion means with different letters differ ( $P < .05$ )

The differences between breeds were significant for all parameters. Quantity of both fecal and urinary N were higher in Cinta Senese pigs that on the whole excreted 20% more N than Large White pigs and consequently retained less nitrogen for new protein synthesis. Such result is confirmed also by the biological value of the protein that in CS reaches values 10% lower than in the improved breed. The biological value of the protein was calculated as the ratio between retained and digested nitrogen and thus it results underestimated with respect to the biological value in the strict sense, which is calculated considering urinary minus endogenous nitrogen. The statistical model employed adjusted the small differences of nitrogen intake between the two diets which showed few differences regarding nitrogen utilization. The greater quantity of digested nitrogen in diet F has been partially offset by the greater urinary excretion (not statistically different); therefore, the N retention was similar. The estimate of the biological value showed no differences between the two diets. Soybean is considered a source of vegetal protein with the best quality. Nevertheless, if we

do not consider the low level of methionine, even the field bean presents a good balance of essential amino acids (Mariscal-Landin *et al.*, 2002; Cevolani, 1991; Piccioni, 1960) and in growing lambs produced good results even when employed at a high dosage (Lanza *et al.*, 1999; Antongiovanni *et al.*, 2002).

Table 5 also reports the global entity of nitrogen excretion expressed as grams/head/day, in order to supply, for Cinta Senese pigs which lack specific reference values, useful parameters to estimate the carrying capacity as required by the recent laws on integrated and organic productions (CEE, 1991).

The ratios among the various nitrogen quotas and ingested N, reported in Table 5, obviously corroborate the worse performances of Cinta Senese pigs and the substantial equivalence of the diets. These values allow a careful comparison with the absolute data reported in literature for analogous trials. Large White pigs of this trial exhibited higher retention and lower excretion than those related by Nasi *et al.* (1995) on the same breed and using diets with similar protein value. On the contrary, the same LW animals

Table 5. Daily Nitrogen intake and balance and biologic value of the protein.

		Breed		Diet		RSD
		Cinta Senese	Large White	Field bean	Soybean	
Metabolic Weight (MW)	kg	19.18 b	24.03 a	21.56	21.63	2.277
N intake /kg MW	g/d	2.075	2.087	2.115 a	2.047 b	0.083
Digested N/kg MW <sup>1</sup>	"	1.720 b	1.827 a	1.804 a	1.744 b	0.097
Fecal N/kg MW <sup>1</sup>	"	0.376 a	0.238 b	0.308	0.306	0.064
Urinary N/kg MW <sup>1</sup>	"	0.879 a	0.757 b	0.836	0.801	0.091
Excreta N /kg MW <sup>1</sup>	"	1.256 a	0.996 b	1.144	1.107	0.106
Retained N /kg MW <sup>1</sup>	"	0.841 b	1.069 a	0.967	0.942	0.139
Biologic Value <sup>1,2</sup>	%	49.04 b	58.12 a	53.35	53.81	6.287
N intake	g/d	39.70 b	50.02 a	45.49 a	44.23 b	1.864
Total N excretion	"	23.02 b	25.77 a	24.88	23.91	2.260
Fecal N / N intake <sup>1</sup>	%	17.87 a	11.61 b	14.54	14.95	3.051
N urine / N intake <sup>1</sup>	"	42.01 a	36.98 b	39.80	39.19	5.065
N excretion / N intake <sup>1</sup>	"	59.88 a	48.60 b	54.34	54.14	5.979
N retention / N intake <sup>1</sup>	"	40.11 b	51.39 a	45.65	45.85	5.979

<sup>1</sup> Data estimated at mean of N intake (44.86 g/d)

<sup>2</sup> Retained N / Digested N

a, b: within criterion means with different letters differ ( $P < .05$ )

showed a ratio between retained and ingested N slightly lower than those of Landrace and Pietrain pigs with analogous weights (51.4% vs. 54%) (Susenbeth *et al.*, 1999).

Table 6 reports the energy partition during the digestive and metabolic processes. The differences between breeds were significant for all parameters confirming that nutritive value has to be considered as a resultant of the interaction between feed and animal also for monogastric species. The greater intake of the improved breed didn't produce greater excretion of energy with a better utilization of the latter. Digestibility of the energy resulted higher in LW than in CS with similar values (88%) to those obtained by Susenbeth *et al.* (1999) with Landrace and Pietrain pigs using diets with lower fiber and greater ether extract contents. Noblet *et al.* (1993), using LW animals fed a diet with fiber content similar to that of the present trial, found analogous values for Energy digestibility but slightly lower values for ME/DE ratio (96%), more in line with those related by Shi and Noblet (1993). Such results are absent in literature for the rustic pig breeds. The comparison between the two protein feeds tested emphasizes the substantial analogy of their nutritive value and no significant differences were found for digestibility, metabolic utilization and energy efficiency.

## Conclusions

The results of this trial allow an initial characterization of the Cinta Senese pig with respect to its ability to utilize the feed. In comparison to Large White pigs, the rustic breed showed a lower ability to digest and to metabolize the protein even if the protein level adopted (16%), common for the improved pigs, may have been too much for this breed and its sarcopoietic capacities. The differences found with respect to fiber utilization leave some open questions that require further analyses since for this breed, often reared outdoors in woodlands, the use of the fibrous fractions could have a remarkable importance. In order to contain protein waste and nitrogenous pollution it is necessary to proceed, setting up specific trials to determine the nutrient requirements of this rustic breed and of the suitable protein levels to create appropriate daily ration and feeding plans.

Soybean and field bean resulted similar in terms of nutritive properties and the field bean with a low-medium tannin level, as used in this trial, up to at least 20% of the diet, seems to not compromise the digestive utilization of the nutrients. Such feedstuff results as a valid alternative protein source even for pigs and it could be used to reconsider traditional feeding or in any case to direct the farm choice towards organic productions that forbid the use of extracted meals. The effec-

Table 6. Energy intake, partition and concentration of the experimental diets.

		Breed		Diet		RSD
		Cinta Senese	Large White	Field bean	Soybean	
E intake	MJ/d	27.38 b	34.49 a	31.01	30.85	1.170
E excretion	"	4.72	5.11	5.05	4.77	1.022
Energy partition:						
-Digestible Energy	%	84.28 b	86.47 a	84.94	85.80	3.026
- Metabolizable Energy	"	82.90 b	85.21 a	83.60	84.51	3.016
EM/ED	"	98.36 b	98.53 a	98.41	98.49	0.192
Energy concentration:						
Gross Energy	MJ/kg DM	17.74	17.74	17.76 a	17.72 b	0.015
Digestible Energy	"	14.95 b	15.34 a	15.09	15.29	0.535
Metabolizable Energy	"	14.71 b	15.12 a	14.85	14.98	0.534

a, b: within criterion means with different letters differ ( $P < .05$ )



tiveness of supplementing the pasture on woodlands of rustic pig breeds with this legume, widespread in the Mediterranean areas of Italy, is therefore confirmed.

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## REFERENCES

- ANTONGIOVANNI, M., ACCIAIOLI, A., FRANCI, O., PONZETTA, M.P., PUGLIESE, C., BUCCIONI, A., BADII, M., 2002. Field bean (*Vicia faba var. minor*) as a protein feed for growing lambs with and without protected lysine and methionine supplementation. *Ital. J. Anim. Sci.* 1: 229-238.
- BURACZEWSKA, L., VALAJA, J., BURACZEWSKA, S., NASI, M., GDALA, J., 1996. Digestibility and availability of protein and phosphorus in pigs fed wet barley protein and wet distillers solids from integrate starci-ethanol production. *Anim. Feed Sci. Tech.* 58: 201-212.
- CEE 1991. Testo unico dei Regolamenti dell'Agricoltura Biologica. Regolamento N. 2092/91.
- CEVOLANI, D., 1991. Con la fava migliorano le produzioni. *Inf. Zoot.* 5: 101-104.
- FREIRE, J.P.B., PEINIAU, J., CUNHA, L.F., ALMEIDA, J.A.A., AUMATRE, A., 1998. Comparative effects of dietary fat and fibre in Alentejano and Large White piglets: digestibility, digestive enzymes and metabolic data. *Liv. Prod. Sci.* 53: 37-47.
- INRA, 1978. Alimentation des ruminants. INRA publications, Versailles, France.
- JANSMAN, A.J.M., HUISMAN, J., VAN DER POEL, A.F.B., 1993. Ileal and faecal digestibility in piglets of field beans (*Vicia faba* L.) varying in tannin content. *Anim. Feed Sci. Tech.* 42: 83-96.
- LANZA, M., PENNISI, P., PRIOLO, A., 1999. Faba bean as an alternative protein source in lamb diets: effects on growth and meat quality. *Zoot. Nutr. Anim.* 25: 71-79.
- MARISCAL-LANDIN, G., LEBRETON, Y., SÈVE, B., 2002. Apparent and standardised true ileal digestibility of protein and amino acids from faba bean, lupin and pea, provided as whole seeds, dehulled or extruded in pig diets. *Anim. Feed Sci. Tech.* 97: 183-198.
- MARTILLOTTI, F., ANTONGIOVANNI, M., RIZZI, L., SANTI, E., BITTANTE, G., 1987. Metodi di analisi per la valutazione degli alimenti di impiego zootecnico. Quaderni metodologici n°8 IPRA-CNR, Roma, Italy.
- NASI, J.M., HELANDER, E.H., PARTANEN, K.H., 1995. Availability growing of minerals and protein of high phytate barley-rapeseed meal diet treated with *Aspergillus niger* phytase or soaked with whey. *Anim. Feed Sci. Tech.* 56: 83-98.
- NOBLET, J., FORTUNE, H., DUPIRE, C., DUBOIS, S., 1993. Digestible, metabolizable and net energy values of 13 feedstuffs for growing pigs: effect of energy system. *Anim. Feed Sci. Tech.* 42: 131-149.
- PICCIONI, M., 1960. Dizionario degli alimenti per il bestiame. Edagricole, Bologna, Italy.
- SARDI, L., MARTELLI, G., PARISINI, P., SCIPIONI, R., 1998. Influenza del metodo di raccolta e di conservazione degli excreta sul bilancio azotato del suino. *Zoot. Nutr. Anim.* 24: 163-170.
- SAS. 1988. SAS user's guide release 6.03. SAS Institute Inc., Cary, NC, USA.
- SCHIAVON, S., RAMAZIN, M., BITTANTE, G., BAILONI, L., GALLO, L., 1996. Valutazione della digeribilità nei suini: confronto fra raccolta totale e sesquiossido di cromo con diete e periodi di campionamento diversi. *Zoot. Nutr. Anim.* 22: 23-32.
- SHI, X.S., NOBLET, J., 1993. Digestible and metabolizable energy values of ten feed ingredients in growing pigs fed ad libitum and sows fed at maintenance level; comparative contribution of the hindgut. *Anim. Feed Sci. Tech.* 42: 223-236.
- SUSENBETH, A., NICKEL, T., DIEKENHORST, A., HOHLER, D., 1999. The effect of Energy Intake, Genotype and Body Weight on Protein Retention in pigs when dietary lysine is the first-limiting factor. *J. Anim. Sci.* 77: 2985-2989.
- VAN KEULEN, J., YOUNG, B.A., 1977. Evaluation of acid-insoluble ash as a natural marker in ruminant digestibility studies. *J. Anim. Sci.* 44: 282-287.
- VAN SOEST, P.J., ROBERTSON, J.B., LEWIS, B.A., 1991. Symposium: Carbohydrate methodology, metabolism and nutritional implications in dairy cattle. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74: 3583-3597.
- ZICARELLI, L., PICCOLO, V., NIZZA, A., INTRIERI, F., PERRUCCI, G., 1979. Indagini sui coefficienti di digeribilità apparente in alcune popolazioni suine meridionali prevalentemente alimentate con sottoprodotti agricoli-industriali diffusi nel mezzogiorno. *Zoot. Nutr. Anim.* 5: 103-109.